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PLATONIC PLATE TECTONICS: ON THE REGULARITY OF THE DISTRIBUTION--ETC(U)

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The geometry of the division of the earth's surface by the major tectonic plates is remarkably regular and symmetric, and several models based on the platonic solids have been proposed to describe this pattern. Under such a model, the "triple points," those points at the boundary of three plates, will have an exceptionally regular distribution. We have tested the distribution of the major triple points using a Monte Carlo computational approach and found it to depart significantly from random, independent and uniform placement of points. Given the natural human tendency to see patterns in situations where, in reality, only unstructured randomness actually exists, the formal testing of hypotheses helps to conform the validity of these structural geologic models.

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PLATONIC PLATE TECTONICS:
ON THE REGULARITY OF THE DISTRIBUTION OF
"TRIPLE POINTS" ON THE EARTH'S SURFACE

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A B S T R A C T

The geometry of the division of the earth's surface by the major tectonic plates is remarkably regular and symmetric, and several models based on the platonic solids have been proposed to describe this pattern. Under such a model, the "triple points," those points at the boundary of three plates, will have an exceptionally regular distribution. We have tested the distribution of the major triple points using a Monte Carlo computational approach and found it to depart significantly from random, independent and uniform placement of points. Given the natural human tendency to see patterns in situations where, in reality, only unstructured randomness actually exists, the formal testing of hypotheses helps to confirm the validity of these structural geologic models.

Throughout the history of the geological sciences there have been sporadic attempts to express the gross structure of the global tectonic framework in terms of simple geometric principles. The conceptual focus of these attempts has been a set of five geometric solids--the platonic solids--that are distinct from all other solids in that each is constructed of identical regular polygons. These are the tetrahedron, the cube, the octahedron, the dodecahedron, and the icosahedron. When Kepler described these five solids as provokingly few in number he expressed the sentiment that led classical geologists to look to the dodecahedron (1-3) and the tetrahedron (4-7) for their theories of global symmetry. An icosahedral model (8) has been tested statistically by the present authors and found to be highly significant.

Mudcracks and basalt columns are well known expressions of a simple principle: When a homogeneous medium is subject to uniform radial tensional stress in two dimensions, it is expected that rupture will result in hexagonal sutures: of all the regular polyhedra that will tessellate a plane, the hexagon has the lowest perimeter to area ratio, and will thus require the least energy to form since the energy required for rupture is proportional to the total length of the ruptures.

Similar considerations might govern the rupturing of a spherical surface; this led Spilhaus (8) to the latest revival of the platonic solid as a paradigm for global tectonic geometry.

Spilhaus noted that the vertices of an icosahedron (the platonic solid composed of 20 equilateral triangles) when projected on the global surface, show apparent coincidence with triple points. His geometry is shown in Figure 1. There are two large pentagonal plates, one centered on Africa and the other on the Pacific Ocean; their centers are antipodal and on the equator. These pentagons are formed by the omission of two antipodal vertices, each shared by five equilateral triangles. The remaining ten equilateral triangles are paired in five rhombs, tessellating the area between the two pentagons and girdling the globe in a North-South band. These rhombs are seen surrounding the central African pentagon in Figure 1 (the antipodal, or Pacific, pentagon appears in this projection to surround the five rhombs). There are three striking symmetries in this configuration: (1) the equatorial position of the two major plate centers, (2) the fact that the southernmost rhomb is centered on the geographic South Pole, and (3) the fact that the plane containing both the magnetic and rotational poles is perpendicular to the diameter connecting the centers of the two pentagons, thus dividing the solid into halves, each an inverted mirror image of the other.

Two kinds of assumptions are necessary to this geometric interpretation. The first deals with the placement of tectonic plates within idealized platonic plates. The identification of a large-scale pattern of global geometry requires the identification of major plates: this immediately raises the question, "what constitutes a major plate." Since Spilhaus' isocohedral model has 10 vertices we constrained our model to that number, but care was taken to ensure that the validity of our statistical results was not compromised by the grouping together of these smaller plates. Geometrically, the Nazca, Cocos, Caribbean, and South American plates are considered to be subsumed within the South American rhomb. Similar groupings are made by placing the Arabian plate within the African pentagon, and the Phillipine plate within the Pacific pentagon. The second kind of assumption deals with the placement of plate boundaries and triple points--which we base entirely on seismic lineations(9). We follow convention by taking the seismic lineations associated with the Vema and Romanche transform fault systems as the boundary between the North and South American plates.

A monte-carlo approach was then used to test the significance of the apparent coincidence of present-day triple points and ideal platonic triple points (10). First, sets of triple points were placed randomly and independently on the globe

so that the probability of a point being in any given region was proportional to the area of that region. Next, a root mean square statistic was used to measure how close the actual angular distance between each point and its nearest neighbor comes to the ideal platonic angular distance of 60 degrees (defined by the vertices of an icosahedron).

Two models were considered. The first used the ten triple points indicated on Figure 1. In a thousand runs, only three showed a better correspondence between random and platonic triple points, indicating that the probability that the present triple point configuration could have arisen by chance is less than 0.01.

The second model included a correction for the grouping together of the smaller plates. Intuitively, the effect of grouping should be to decrease the representation of small nearest neighbor distances, thereby forcing a smaller value of the computed mean square statistic. To ensure that the observed statistical significance is real and was not due to this effect, we also performed a simulation as follows. For samples of seventeen points on the globe (thus including the extra triple points lost by our plate grouping), the nearest neighbor distances were calculated. Only the ten largest of these distances were used in computation of the mean square statistics,

simulating the exclusion of small plates with close triple points. Surprisingly, no significance seems to have been lost in using this procedure. In 1000 runs of this simulation, no replicate showed as regular a configuration as the ten actual triple points. This result is possible because while the mean value of the simulated statistic is closer to the actual value, the variance is smaller than it was with the previous models.

Statistical theory now permits us to reject the null hypothesis that the triple points are randomly and independently distributed, and allows us to conclude that there is a strong systematic component in the placement of these points. Having formally tested these hypotheses, we are protected in part from the natural human tendency to see structured patterns in situations where, in reality, only unstructured randomness actually exists. By concentrating our attention on triple junctions, we did not directly consider the distribution of hot spots (11), nor did we test the significance of the linear correspondence between real plate margins and "ideal" platonic plate margins, although it should be noted that the real and platonic margins are topologically identical. The greatest divergence between real and ideal margins is seen in the southwest Pacific (Fig. 1); this is enhanced by the projection to the extent that the true plate margin appears to be disjunct at the edge of the map.

If these results are valid, as their statistical significance suggests, then it is likely that this kind of configuration has persisted through at least some part of geologic history. This would place historical and geographic constraints on continental movements that could aid in palinspastic reconstruction. Further, the heuristic implications of this "plato effect" for analysis of whole-earth convection geometry, the deep structure of the earth, plate motion (12,13), and extra-terrestrial geology (in planets with plate motion) are obvious.

The tetrahedral and dodecahedral theories of the 19th and early 20th centuries may have held that the continental configuration was as immutable as its ideal platonic counterpart, but the spirit of these theories remains consistent with present-day dynamic models of the earth. It was the vision of these earlier platonists that natural geometric regularities were evidence of deeper underlying principles, and that by understanding the causes of these regularities one could gain valuable insights into the nature of mechanisms governing natural process.

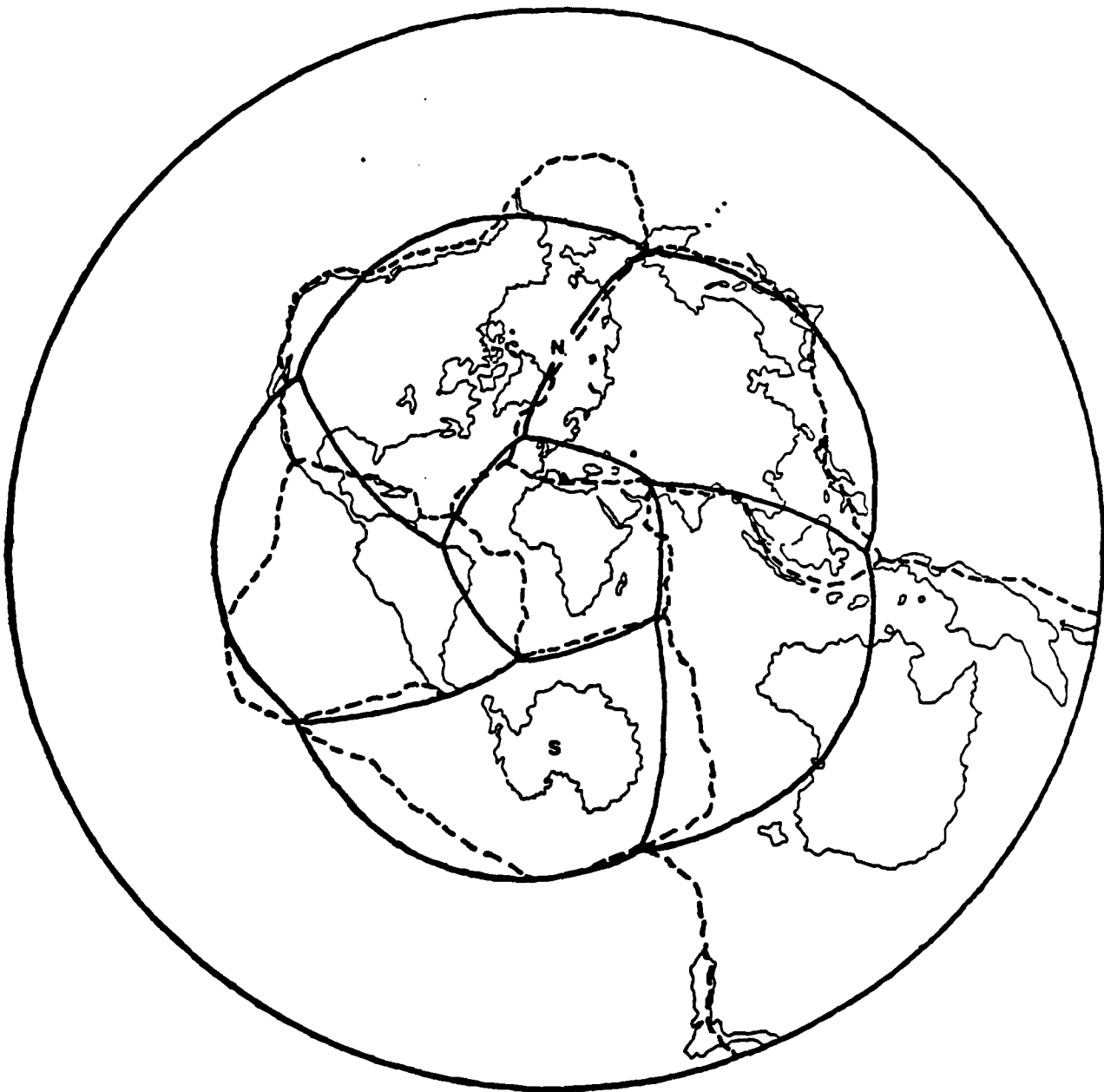


FIGURE 1. Stereographic projection centered on Africa. Heavy solid lines represent a projection of an icosahedron as described in the text. Dotted lines represent projections of seismic lineations after grouping of minor plates.

The apparent discontinuity in the plate margin in the area of the Tonga-Kermadec trench is caused by increased edge distortion inherent in stereographic projections. Modified after (14).

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12. See various citations in Holmes, A. Principles of physical geology. 1033-1041 (1964).

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14. Spilhaus, A. Smithsonian, Aug.,1976, p. 57.